Real-Time Operational Considerations

Initial Training Program

Student Guide

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State & Member Training
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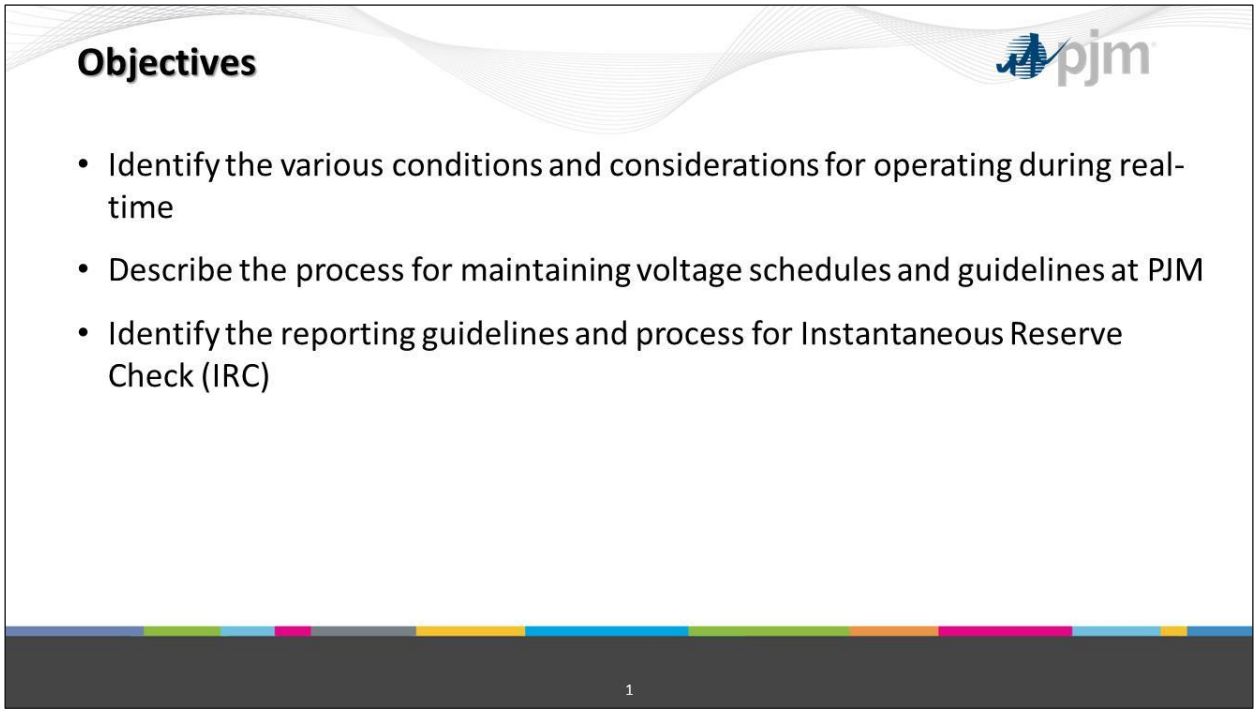
Objectives


Objectives
pjm
• Identify the various conditions and considerations for operating during real-time
• Describe the process for maintaining voltage schedules and guidelines at PJM
• Identify the reporting guidelines and process for Instantaneous Reserve Check (IRC)
1

Unit Output Changes

Unit Output Changes

- Generation owners planning to start generation resources are required to call the PJM Control Center at least 20 minutes prior to bringing the unit online.
- Generation owners must also notify PJM when:
  - Taking a unit offline
  - Any change in output greater than or equal to 50 MWs (assuming the unit is not following SCED)

2

Unit Hourly Changes

Unit Hourly Changes

- If a status changes during real-time (for example, the unit limits change), the Operating Company uses the Unit Hourly Updates web page in Markets Gateway to provide the updated status

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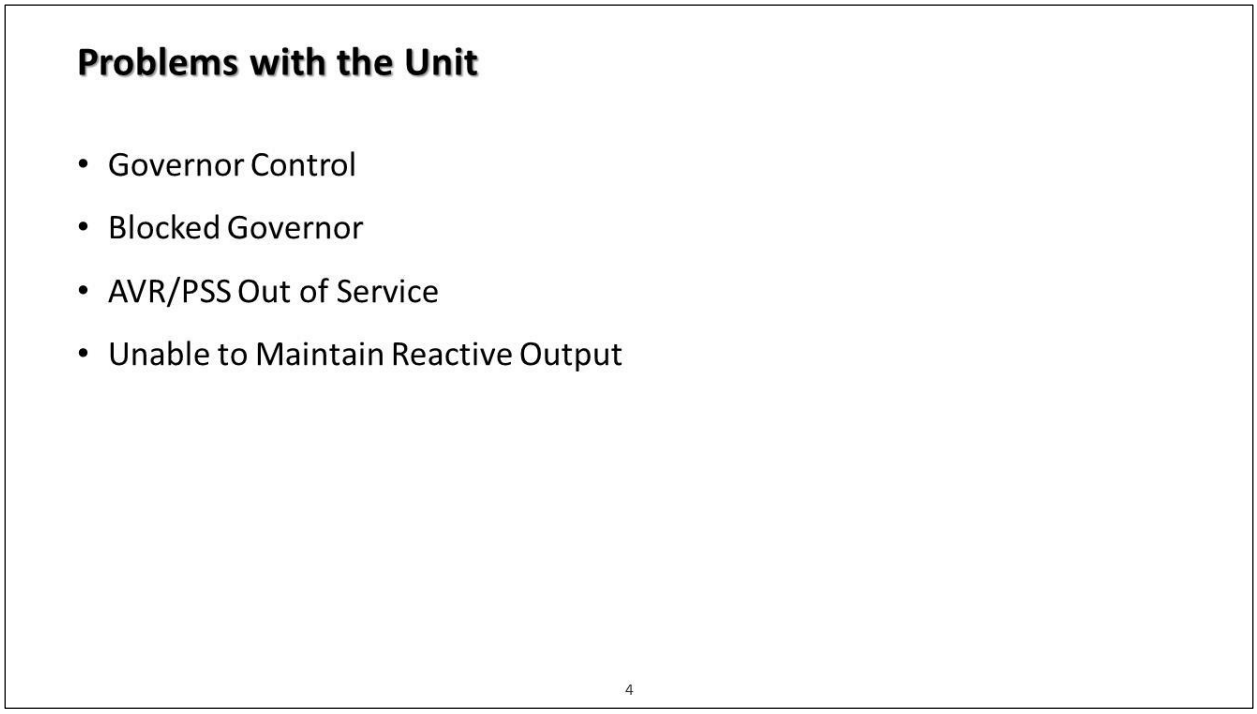
Problems with the Unit



Deviations from Day-Ahead Market for Scheduled Resources

Deviations from Day-Ahead Market for Scheduled Resources

- If a generation resource has been scheduled in the Day-ahead Market and wishes to deviate from that schedule (i.e. not run), the generation owner should contact the PJM Master Coordinator to determine the ramifications of this course of action
- The guideline for notifying PJM of deviations for pool scheduled resources will be the greater of the notification time plus startup time or 45 minutes
- The generation owner will always be responsible for all imbalance and operating reserve charges

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Deviations from Day-Ahead Market for Scheduled Resources

- If PJM determines that the generation resource is not needed for reliability purposes for the operating day, the generation owner can decide to not run the resource and no forced outage will be incurred.
- If PJM determines that the resource is needed for reliability purposes, PJM will inform the generation owner. The generation owner may still elect to not run the resource, but a forced outage for the duration of the scheduled operation of the resource will be generated.

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Governor Control

Governor Control

Mechanism that senses machine speed and adjusts the input to the prime mover to change the mechanical power output of the machine to compensate for changes in load restoring frequency to nominal value

- Fossil Unit: Controls the input of steam to the high pressure stage of the turbine
- Hydroelectric Unit: Controls the flow of water into the hydraulic turbine
- Combustion Turbine Unit: Controls the amount of fuel flow into the combustor
- Wind Turbine: Controls the pitch of the blades

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Blocked Governor

Blocked Governor

- Blocking the governor bypasses the governing feedback mechanisms maintaining the generator at a fixed output level
- Fewer units able to respond via Governor Control can lead to:
  - Longer period of time needed to restore system frequency to normal
  - System stability is impacted due to higher deviations in frequency

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Governor Status Changes

Governor Status Changes

- Blocking a governor:
  - Notify PJM's Generation Dispatcher verbally of the outage
  - Create and submit an eDART ticket to notify PJM of an outage to the governor on the unit
  - Initiate the associated eDART governor ticket by submitting a "Start" time for the equipment outage
- Placing a governor in service:
  - Notify PJM's Generation Dispatcher verbally of the governor being placed into service
  - Close out the associated eDART governor ticket by submitting an "End" time for the equipment outage
  - Update the unit status in Markets Gateway

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Generator AVR/PSS Status Reporting

Generator AVR/PSS Status Reporting

Per NERC Standard VAR-002-4.1 (excerpts)

- Each Generator Operator shall notify its associated Transmission Operator within 30 minutes of:
  - R3. Any status change on a generator's AVR, power system stabilizer, or alternative voltage controlling device
  - R4. Becoming aware of a change in reactive capability due to factors other than a status change described in Requirement R3

- Reporting of AVR status and Reactive Capability changes accomplished via eDART generator reporting

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Generator AVR/PSS Status Reporting

PJM Manual 14-D

- Whenever a unit's Automatic Voltage Regulation (AVR) status is off (or is planned to be off), the generator's owner/operator must enter a ticket via eDART
  - Excluding the time period when a generator is in the startup or shutdown mode
- For real-time changes, the generator's owner/operator must also notify the PJM Master Dispatcher (PD) and the respective TO by phone

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Generator AVR/PSS Status Reporting

PJM Manual 14-D

- Generation Owners/Operators must coordinate any voltage schedule issues with PJM and the TO
  - Includes issues with stability, automatic voltage regulator, and power system stabilizer outages
- If automatic voltage regulating devices are out-of-service, the Generator shall provide manual voltage regulation to maintain the prescribed voltage schedule

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Generator AVR/PSS Status Reporting

PJM Manual 14-D

- The Generator must notify PJM and the TO with as much lead-time as possible prior to performing all automatic voltage regulator (AVR) and power system stabilizer (PSS) maintenance
- Notifications of unplanned outages on AVRs and/or PSSs must be communicated to PJM and the TO as soon as possible but no later than within 30 minutes of the occurrence
- For modeling accuracy the provision of telemetered AVR and PSS status points by Generator Operators to PJM is preferred

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What Reactive Reserve Information is Reported?

What Reactive Reserve Information is Reported?

- Upon the request of PJM, all TOs will provide a Reactive Reserve Check (RRC) report to PJM
  - PJM generally requests a RRC during capacity deficient conditions or when a Heavy Load Voltage Schedule Warning is implemented
  - RRCs are also done periodically for testing/training purposes
- TOs must report MVAR reserve for all units connected to their system
  - MVAR Reserve is the difference between the present operating points, leading or lagging, and the actual lagging MVAR capability

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What Reactive Reserve Information is Reported?

- MOCs/GOs must report to the TO any limitation or restriction on their unit which would prevent it from being able to follow its reactive capability curve as recorded in eDART
  - Unless an eDART ticket already exists documenting the condition
- This ensures the TO is submitting accurate information for the RRC

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Voltage Limits

Voltage Limits

Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse.

- Equipment affected by operation within/outside of voltage limits include:
  - Motors
  - Transformers
  - Generators
  - Loads
  - Capacitors/Reactors

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Voltage Limits

- Voltage limits are determined and based on system reliability and manufacturers' recommendations
  - Maintain system reliability
    - High voltage limit protects equipment from damage
    - Low voltage limit protects the system from voltage instability and equipment damage
  - Established by equipment manufacturers. ANSI Standards provide basis for voltage schedules
    - 97.5% - 105.0% Normal (Customer voltage)
    - 95.0% - 105.8% Emergency (Customer voltage)

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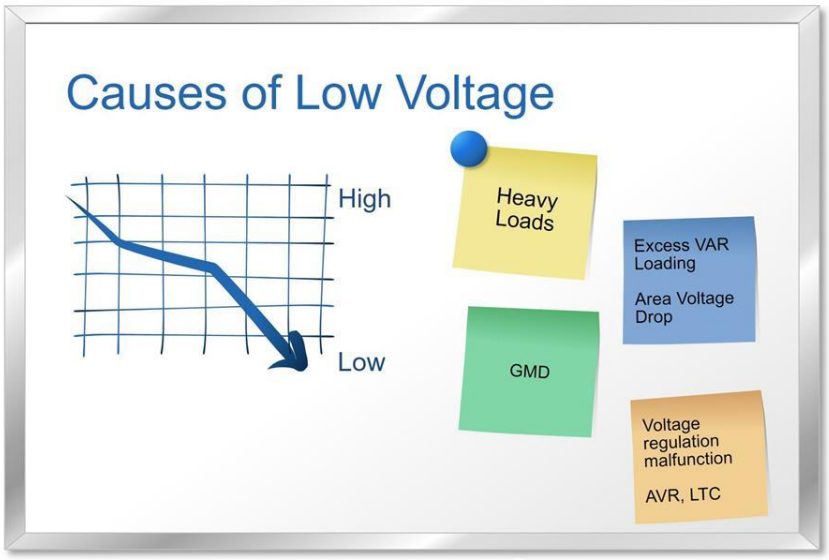
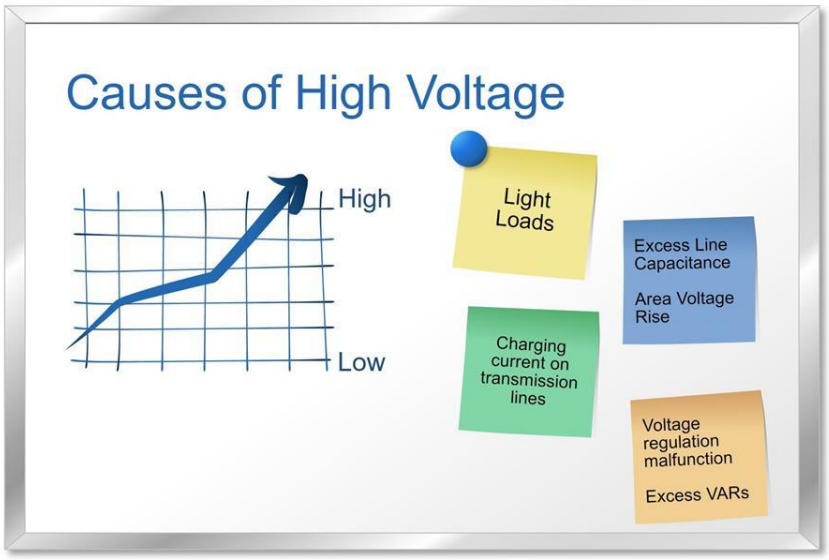
Causes of Low Voltage



Causes of High Voltage



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Detection of Voltage Problems

Detection of Voltage Problems

- Observe Critical Bus Voltages
  - Where do problems appear first?
- Observe Voltages in an Area
  - Determine if deviation is on a single bus or over an area on the system
- Observe Voltage Alarms

- Monitoring Sources
  - EMS, map board, trends, field reports, customer complaints
  - Monitor voltages, limits, alarms, and MVAR flow

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VAR Sources and Sinks

VAR Sources and Sinks

- Voltage Control Means MVAR Control
  - Control of voltage and reactive power are inseparable!
    - MVAR sources support or hold up voltages
      - Capacitors
      - Generators / Synchronous Condensers
      - Static VAR Compensators
      - System Capacitance
    - MVAR sinks pull down voltages
      - Reactors
      - Generators / Synchronous Condensers
      - Loads
      - System Inductance/MVAR Losses
      - Static VAR Compensators

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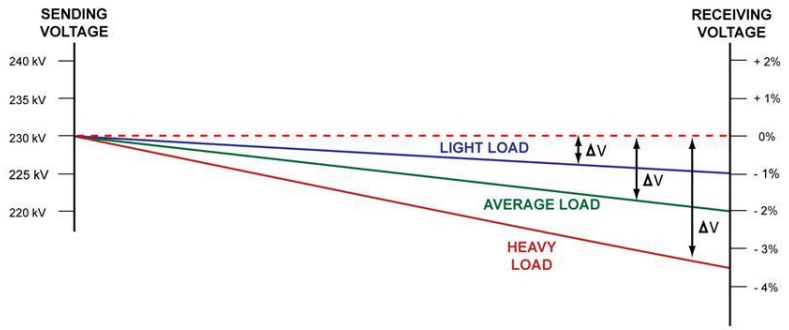
System Voltage Characteristics

System Voltage Characteristics

- Results - a constantly changing voltage profile



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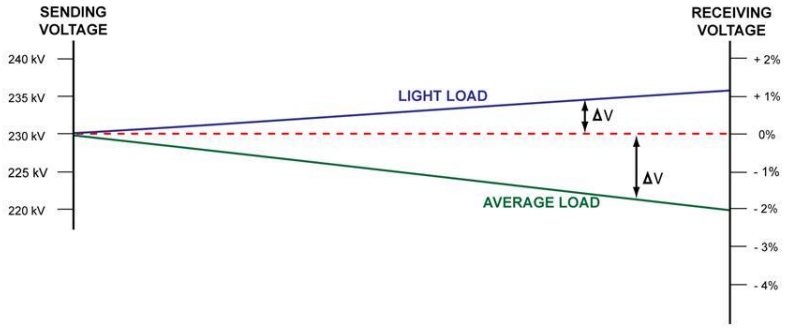
System Voltage Characteristics

- Results - for light loads, voltage can rise due to low losses and line capacitance



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Voltage Limits

Voltage Limits

Consequences of deviations from voltage limits

- Low voltage
  - Dim lights
  - Slow heating of heating devices
  - Difficulty starting motors
  - Overheating/damage to motors
- High voltage
  - Light bulb life decreased
  - Electronic devices life decreased

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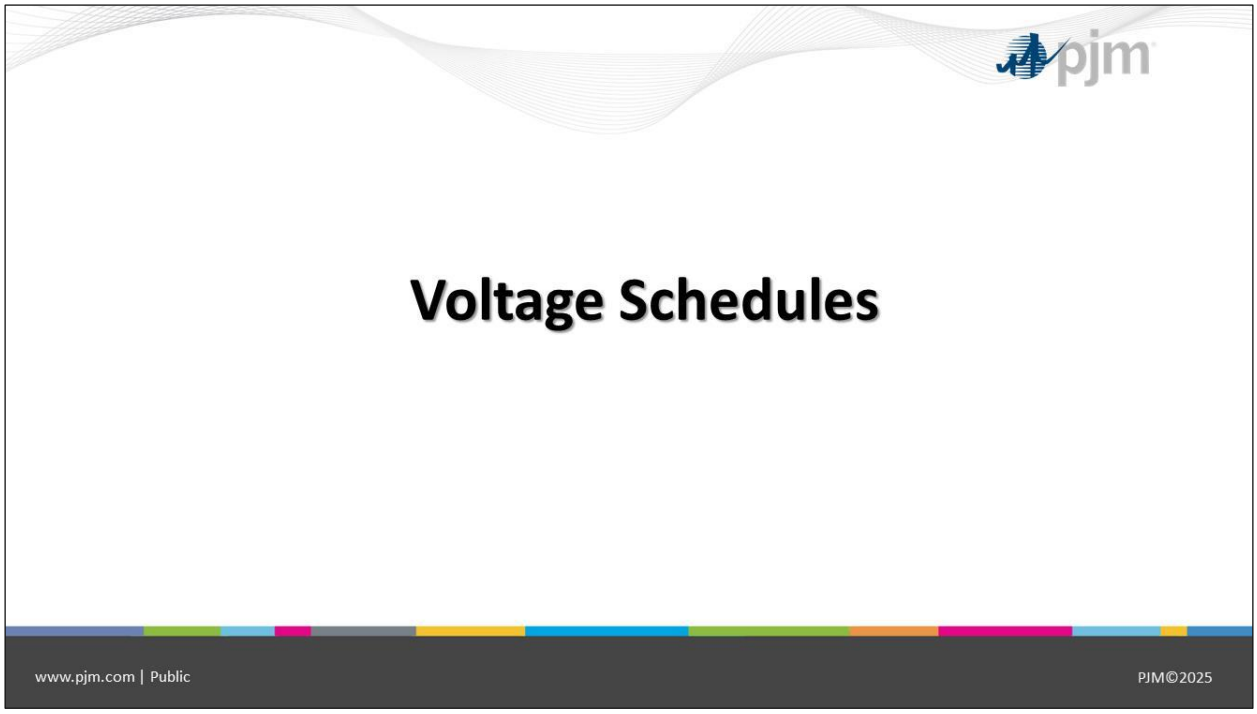
Voltage Schedules



Voltage Schedules

- NERC Standard VAR-001-5 states each TOP shall:
  - Specify a voltage or reactive power schedule (setpoint and bandwidth)
  - Provide the schedule to the GOP, and direct the GOP to follow the schedule with its AVR in service (automatic)
  - Provide the GOP with the notification requirements for deviations from the schedule
  - Provide the criteria used to develop the schedules
- The TO/TOP Matrix identifies shared or assigned responsibilities

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Voltage Schedules

PJM requires the following subset of generators to follow voltage schedules

- Individual generating units greater than 20 MVA
- Generators that aggregate to 75 MVA or greater connected to a common bus
- Black start generators
- Any other Generation Owner that request a voltage schedule

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Voltage Schedules

Voltage schedules are managed via eDART

- TO submits a specific voltage schedule or can use the PJM default schedules
- PJM reviews the voltage schedules and approves any exemption requests
- The GO acknowledges the voltage schedule

PJM Default Generator Voltage Schedules									
Voltage Level (kV)	**765**	**500**	**345**	**230**	**161**	**138**	**115**	**69**	**66**
Schedule (kV)	760.0	525.0	350.0	235.0	164.0	139.5	117.0	70.0	67.0
Bandwidth (+/- kV)	+/- 10.0	+/- 8.0	+/- 7.0	+/- 4.0	+/- 4.0	+/- 3.5	+/- 3.0	+/- 2.0	+/- 1.5

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Voltage Schedules

- PJM will direct:
  - A generator to deviate from its default voltage schedule
  - A generator to adjust MW output to allow for more MVAR capability
  - A generator to come/remain online for voltage support. This includes operating as a synchronous condenser
- The TO will request generators to make any necessary MVAR output changes, as long as the generator stays within its voltage schedule

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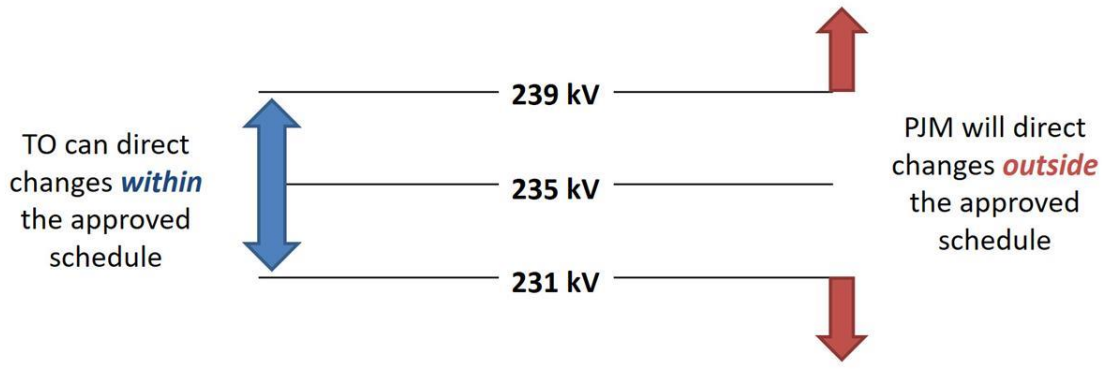
Voltage/Schedule Adjustments

Voltage/Schedule Adjustments



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Voltage Schedules

Voltage Schedules

The Generator Owner/Operator shall:

- Follow the voltage schedule with the AVR in service
  - If AVR is out of service, must notify PJM and TO
- Communicate voltage schedule concerns to PJM via the TO for resolution
  - Additional reserves based on D-Curve:
    Generator is required to notify PJM and the TO that they cannot maintain their assigned voltage schedule and provide updated D-Curve via eDART
  - Operating at full lead/lag MVAR based on submitted D-Curve:
    Generator is required to notify PJM and the TO that they cannot maintain their assigned voltage schedule
    PJM will determine if MW reduction is required in order for unit to adjust MVAR output to maintain voltage schedule

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Overview

Overview

- Generator Voltage Schedules through PJM's eDART application ensures consistent tracking and reporting protocols for communication between PJM, TOs and GOs concerning generator voltage schedules
- PJM shall initiate a voltage schedule review on an annual basis
  - TOs shall review and update each schedule with the GOs acknowledgement
- Allows TOs to specify, and PJM to approve, Voltage Schedules for all generating units to include:
  - Submitting a new ticket, Editing an existing ticket, handling of exemptions, reporting, processing and seasonal verification

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Overview

- Generators that require a Voltage Schedule:
  - Individual generating units > than 20 MVA
  - Generators aggregating to 75MVA or > connected to a common bus
  - Black start generators
  - Any other GOs that request a voltage schedule
- Generators added to eDART that meet the above criteria will have a blank "Needs Schedule" ticket automatically entered requiring a new Voltage Schedule ticket to be submitted by the TO

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Overview

- Each Voltage Schedule ticket shall contain:
  - A target voltage schedule
  - Upper and lower bandwidths
  - The regulated transmission bus
- Each schedule can either be PJM's default voltage schedule, or a schedule as designated by the local Transmission Owner

PJM Default Generator Voltage Schedules									
Voltage Level (kV)	**765**	**500**	**345**	**230**	**161**	**138**	**115**	**69**	**66**
Schedule (kV)	760.0	525.0	350.0	235.0	164.0	139.5	117.0	70.0	67.0
Bandwidth (+/- kV)	+/- 10.0	+/- 8.0	+/- 7.0	+/- 4.0	+/- 4.0	+/- 3.5	+/- 3.0	+/- 2.0	+/- 1.5

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Overview

- A voltage schedule can be based on the TO's specifications:
  - Voltage
  - Reactive Power
  - Power Factor
  - Manual (TO Exemption)

AVR Operating Mode	Expected Generator Response
Automatic controlling voltage (voltage schedule)	Reactive output varies based on the grid system needs to maintain the reference voltage within the assigned voltage schedule's bandwidth up to the reactive capabilities of the generator. This is the standard voltage control operating mode for most generators in PJM.
Automatic controlling MVARs (MVAR schedule)	Reactive output remains steady based on scheduled MVARs
Automatic controlling power factor (power factor schedule)	Reactive output varies based on the real power output of the generator to maintain a constant ratio of real power versus apparent power (constant power factor)
Manual	Reactive output varies based on the manual adjustments made by the plant operator

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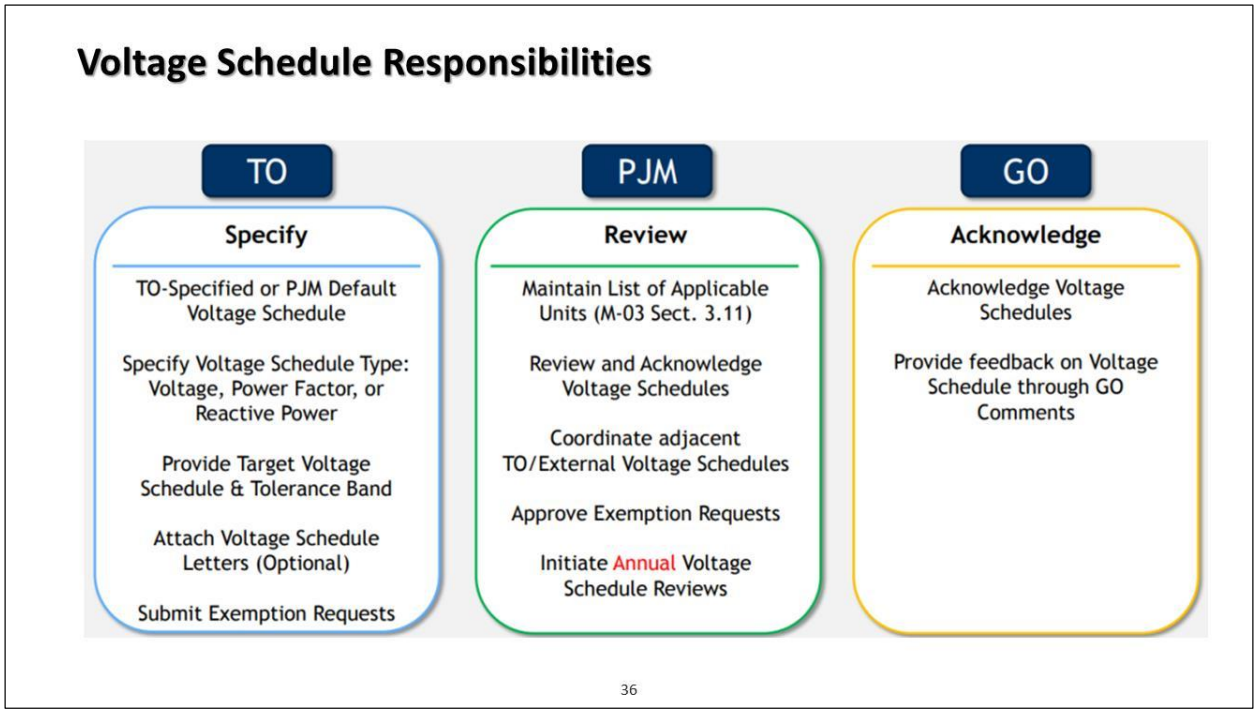
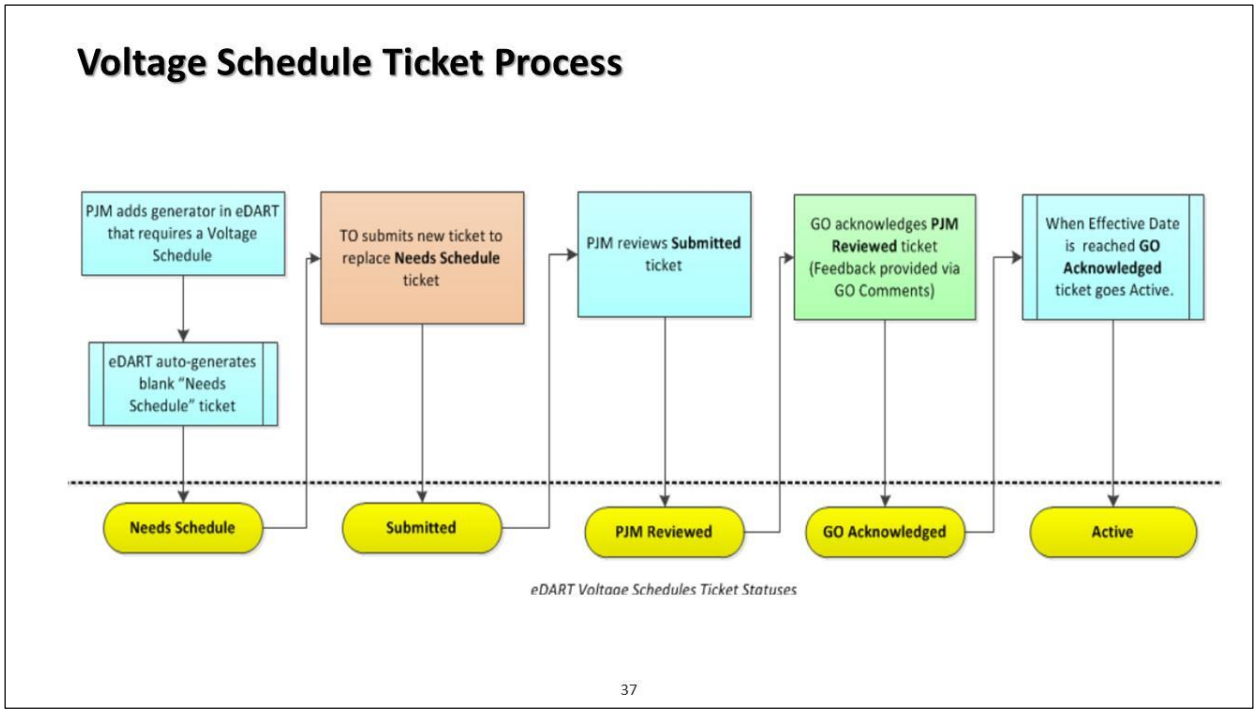
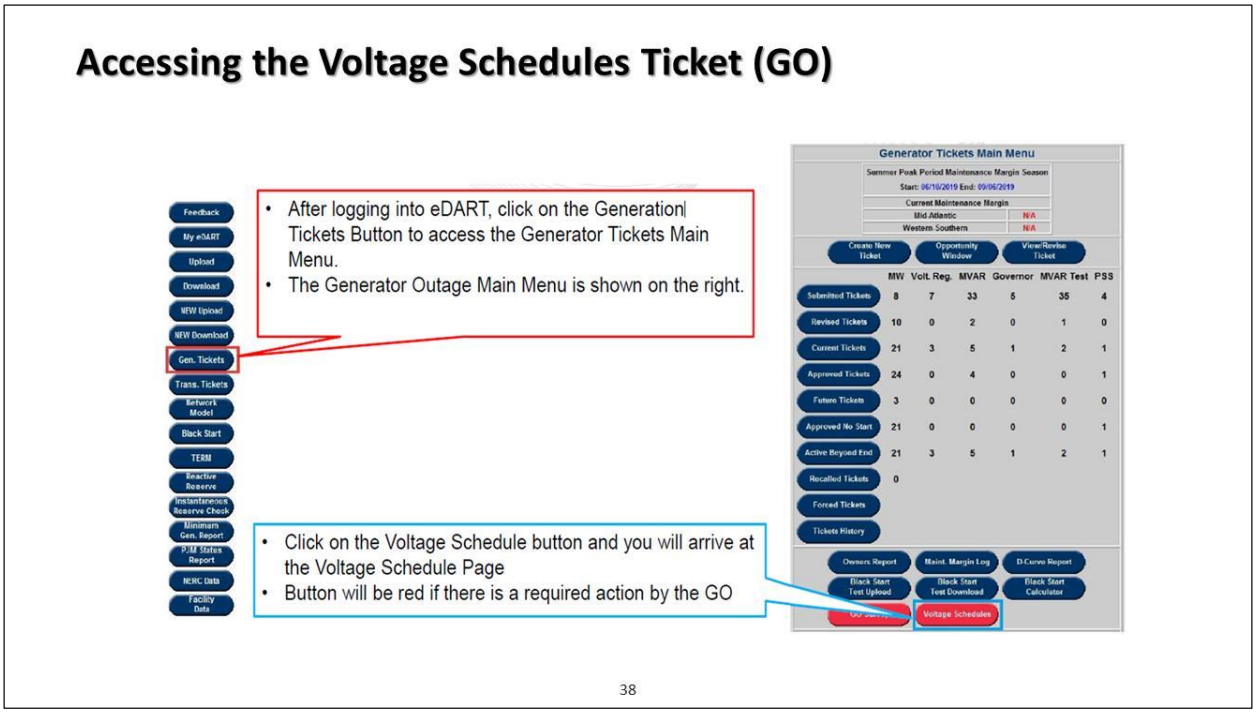
Voltage Schedule Responsibilities



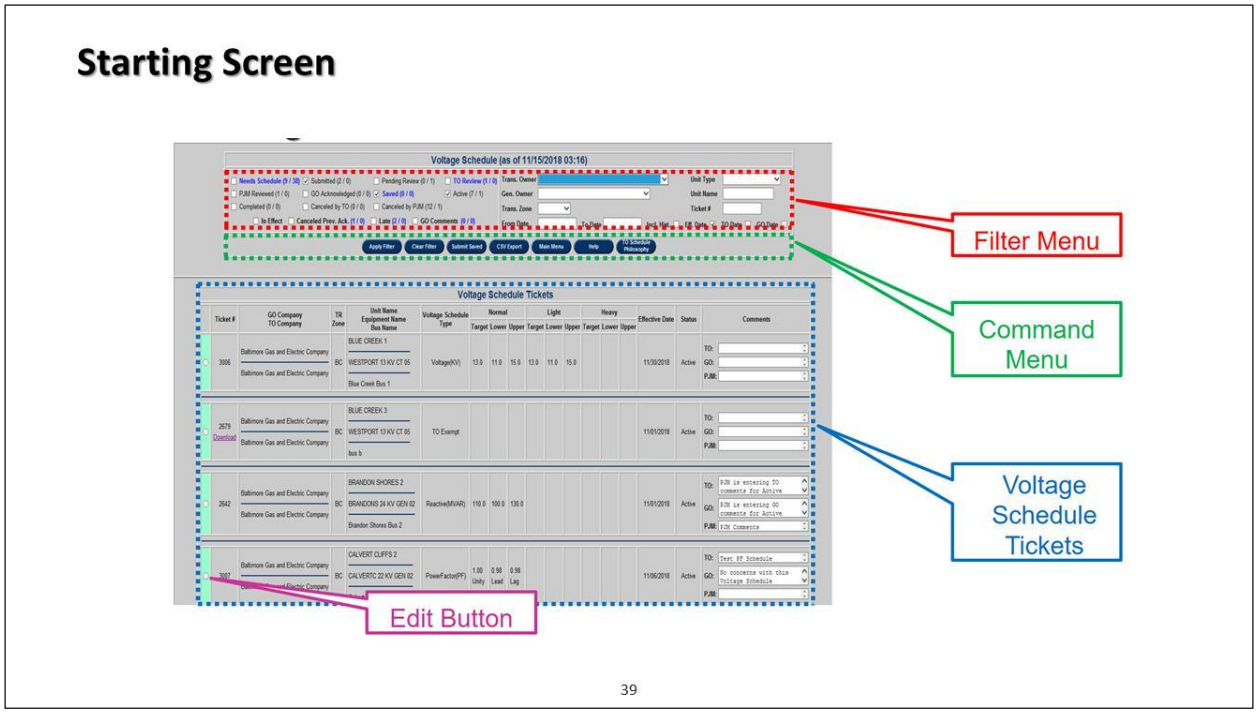
Voltage Schedule Ticket Process



Accessing the Voltage Schedules Ticket (GO)

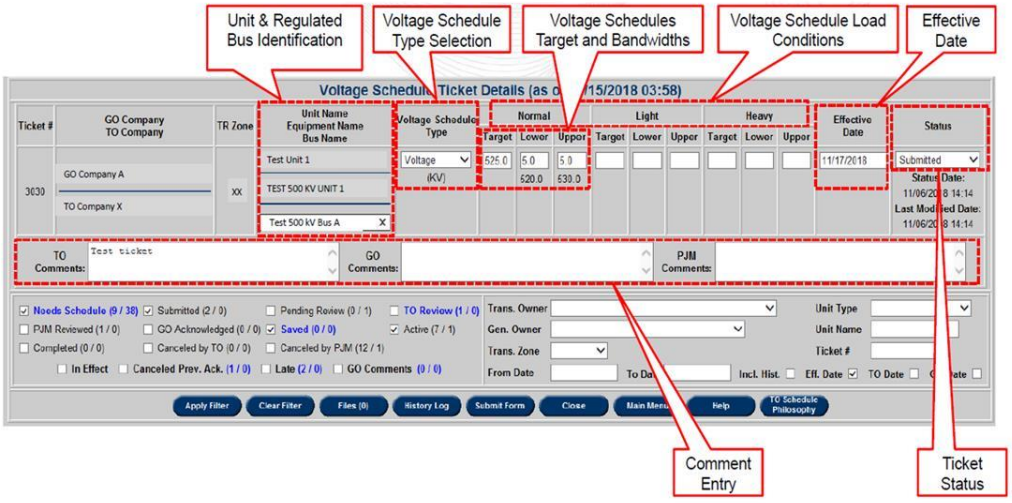


Starting Screen



Ticket Details

Ticket Details



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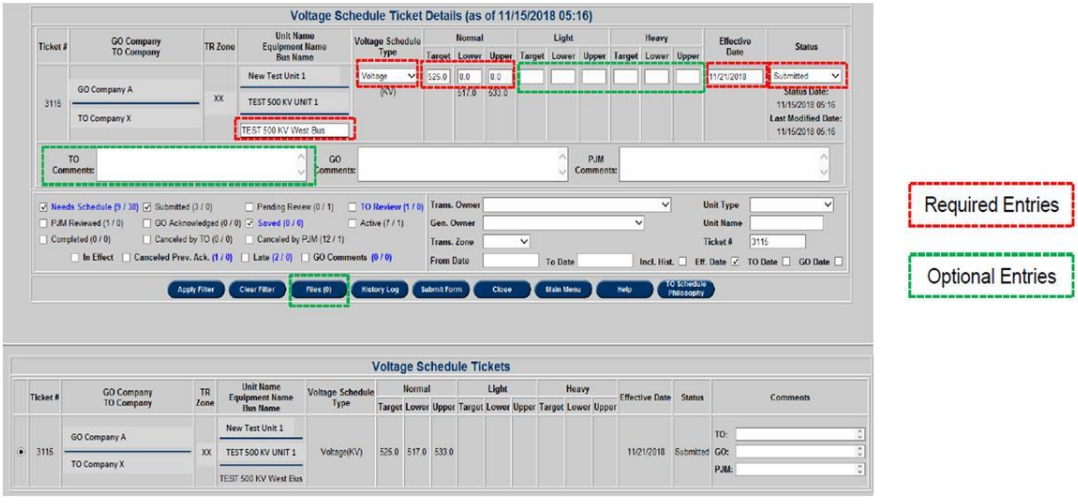
Ticket Details



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Ticket Details

- The “Effective Date” is the day the ticket is in effect:
  - Applies to all four types of Voltage Schedules
  - The date cannot be the day the ticket was submitted
  - Earliest “Effective Date” allowed is the next day (submission date + 1 day)
  - No two tickets can start on the same day.
  - Error returned if user submits a future ticket with the same effective date as one that already exists for the unit.

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Acknowledging a Reviewed Voltage Schedule Ticket

Acknowledging a Reviewed Voltage Schedule Ticket

- A ticket in “GO Acknowledged” status will turn “Active” once the effective date of the ticket has been reached
- Old Active Voltage Schedule tickets are automatically “Completed” once a new GO Approved ticket turns active by reaching its Effective Date.
- Active tickets are highlighted by a mint-green tab on the Voltage Schedule Tickets listing

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PJM Instantaneous Reserve Check

PJM Instantaneous Reserve Check

- IRC is used to verify PJM's reserve situation
  - ***ALL*** generators must validate/update their reserve information to PJM when requested
  - A minimum of one request via PJM All-Call before each daily peak
    - Usually 30 to 45 minutes prior to the peak
  - Could be more than 2 requests in a day depending on system conditions
    - Establishes benchmarks which can be used to estimate reserves
    - Determines if reserve shortages exist and what if any emergency procedures should be declared
    - Reserve quantities should reflect current regulation assignments

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Operating Reserves

Operating Reserves

- Operating Reserves: Offline + Online
  - Offline (the lesser of):
    - Offline Eco Max/Spin Max
    - Ramp Rate X (30 min – TTS)

- Time To Start (TTS) = Notification Time + Startup Time

  NOTE: Offline Reserve Units that have a TTS ≤ 30 minutes shows should be included
  - Online (the lesser of):
    - Ramp rate x 30 minutes
    - Eco Max/Spin Max – Current MW level

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Operating Reserves Example

Gen	Fuel Type	Emerg Min	Eco Min	Eco Max	Emerg Max	Current MW output	Ramp Rate MW/Min	TTS
Amus	Hydro	10	15	180	200	80	20	10 Min
Grange	CT	0	0	600	600	0	10	5 Min

- Calculate the Operating Reserves for the Amus and Grange units
  - Amus, Online Unit
    - (Ramp Rate X 30 Min) = (20 MW X 30 min) = 600 MW
    - (Eco Max – Current Output) = (180 MW – 80MW) = **100 MW**
  - Grange, Offline Unit
    - Eco Max = 600 MW
    - (Ramp Rate X (30 min – TTS)
      = 10 X (30 mins – 5 mins) = **250MW**

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Synchronized Reserves

Synchronized Reserves

- Synch Reserve = lesser of:
  - Ramp Rate * 10 min
  - Eco Max – current MW level

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Synchronized Reserves Example

Gen	Fuel Type	Emerg Min	Eco Min	Eco Max	Emerg Max	Current MW output	Ramp Rate MW/Min	TTS
Amus	Hydro	10	15	180	200	80	20	10 Min
Grange	CT	0	0	600	600	0	10	5 Min

- Calculate the Synchronized Reserves for the Amus and Grange units
  - Amus:
    - (Ramp Rate X 10 Min) = (20 MW X 10) = 200MW
    - (Eco Max – Current output) = (180 MW – 80 MW) = **100 MW**
  - Grange:
    - **0 MW** – Offline Unit

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Quick Start Non-Synchronized Reserves

Quick Start Non-Synchronized Reserves

- Offline Reserve Units that have a TTS ≤ 10 minutes should be included
- Non-Synch Reserve = lesser of:
  - Ramp Rate * (10 minutes - TTS)
  - Eco Max

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Quick Start Non-Synchronized Reserves Example

Gen	Fuel Type	Emerg Min	Eco Min	Eco Max	Emerg Max	Current MW output	Ramp Rate MW/Min	TTS
Amus	Hydro	10	15	180	200	80	20	10 Min
Grange	CT	0	0	600	600	0	10	5 Min

- Calculate the Quick Start Reserves for the Grange unit
  - Grange:
    - Eco Max = 600 MW
    - Ramp Rate * (10 min – TTS)
      - (10 MW X (10 min – 5 min)) = (10 MW X 5 Min) = **50 MW**

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Secondary Reserves

Secondary Reserves

- Secondary Reserve = Operating Reserve - Primary Reserve
- Supplemental Reserve for Amus & Grange:
  ((Amus Operating + Grange Operating) - (Amus Primary + Grange Primary))
  - ((100 MW + 250 MW) - (100 MW + 50 MW)) = (350 MW - 150 MW) = **200MW**

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PJM Instantaneous Reserve Check

PJM Instantaneous Reserve Check

- Once data is received from Member, PJM determines:
  - PJM Operating Reserve
  - Adjusted Primary Reserve vs. requirement
  - Adjusted Synchronized Reserve vs. requirement
  - Unaccounted for capacity
  - Area Synchronized Reserve levels
- PJM compares values calculated from Member data to reserve requirements to determine deficiencies
- PJM report results to Members via eDART

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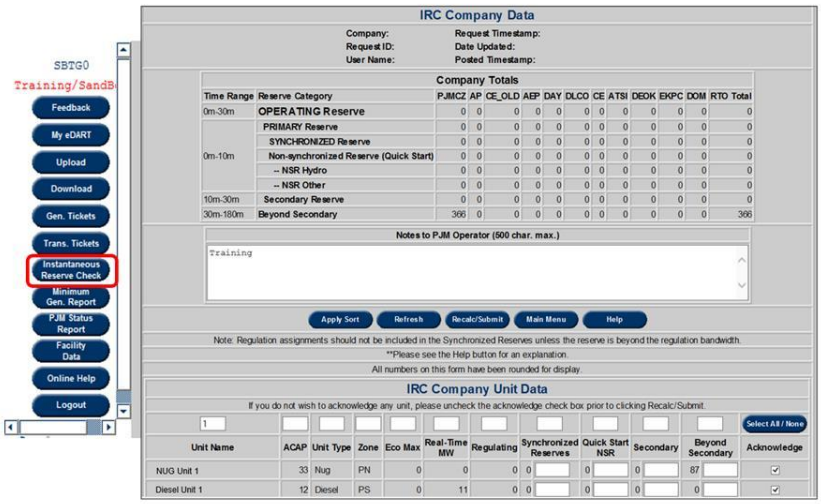
PJM Instantaneous Reserve Check



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Instantaneous Reserve Check Exercise

Instantaneous Reserve Check Exercise

- Given the portfolio, fill out the IRC data in eDART with the following values:
  - Synchronized Reserve
  - Quick Start Non-Synchronized Reserves
  - Secondary
  - Beyond Secondary

Click here for the IRC Exercise

Unit Name	ACAP	Unit Type	Control Zone	Eco Max	Real-Time MW	Ramp Rate MW/Min	TTS (minutes)	Regulating	Synchronized Reserves	Quick Start NSR	Secondary	Beyond Secondary
Columbus	200	Hydro	AEP	225	0	25	5	0				
Lexington	688	Fossil	AEP	700	680	8	360	0				
Bedford	290	CC	AP	300	210	15	20	0				
Elmwood	1200	Nuclear	CE	1200	1200	5	2880	0				
Whitehouse	400	Hydro	DAY	400	0	30	14	0				
Pleasantville	66	CT	DLCO	70	45	4	3	0				
Richmond	585	CT	DOM	600	0	50	7	0				
Corolla	24	CT	DOM	25	0	3	2	0				
Elizabeth	550	Fossil	PJMCZ	590	410	12	720	0				
Lebanon	1147	Fossil	PJMCZ	1150	620	10	1200	0				

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Instantaneous Reserve Check Simulation Answers

Unit Name	ACAP	Unit Type	Control Zone	Eco Max	Real-Time MW	Ramp Rate MW/Min	TTS (minutes)	Regulating	Synchronized Reserves	Quick Start NSR	Secondary	Beyond Secondary
Columbus	200	Hydro	AEP	225	0	25	5	0	0	125	100	0
Lexington	688	Fossil	AEP	700	680	8	360	0	20	0	0	0
Bedford	290	CC	AP	300	210	15	20	0	90	0	0	0
Elmwood	1200	Nuclear	CE	1200	1200	5	2880	0	0	0	0	0
Whitehouse	400	Hydro	DAY	400	0	30	14	0	0	0	400	0
Pleasantville	66	CT	DLCO	70	45	4	3	0	25	0	0	0
Richmond	585	CT	DOM	600	0	50	7	0	0	150	450	0
Corolla	24	CT	DOM	25	0	3	2	0	0	24	1	0
Elizabeth	550	Fossil	PJMCZ	590	410	12	720	0	120	0	60	0
Lebanon	1147	Fossil	PJMCZ	1150	620	10	1200	0	100	0	200	230

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Click here for the IRC Exercise

Instantaneous Reserve Check Tool

Instantaneous Reserve Check Tool

- The Instantaneous Reserve Check (IRC) is used to verify the PJM reserve situation at a given moment in time
- Unit by Unit Design:
  - Reserve data is pre-populated from PJM Markets and EMS systems on a Unit by Unit basis
  - User option to acknowledge reserve values: all units or per unit
  - User entry fields to submit changes to reserve values
- IRC Self-Check:
  - Display of current reserve data when IRC is not in progress

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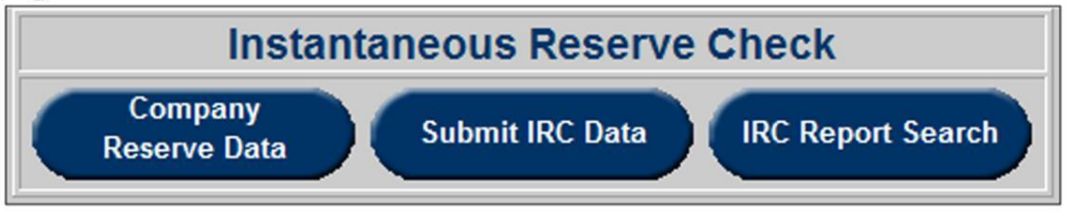
Instantaneous Reserve Check

Instantaneous Reserve Check

- Company Reserve Data:
  - Display of PJM view of company reserve data
  - Updated every 5 minutes
  - Available only when IRC is not in progress



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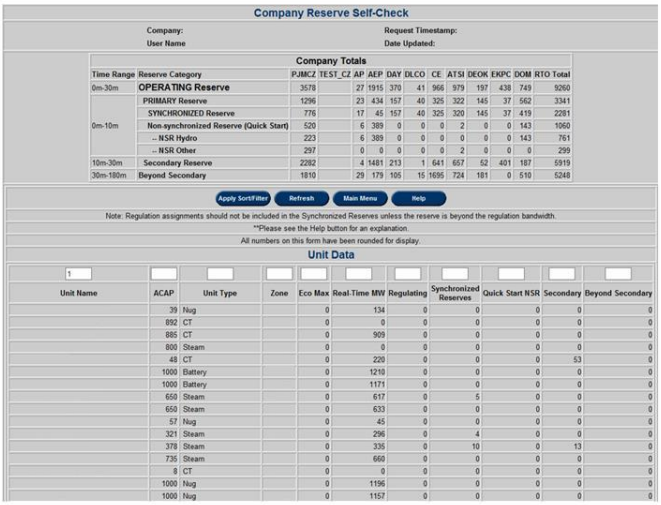
Company Reserve Check

Company Reserve Check



Company Reserve Self-Check

Company:
User Name
Request Timestamp:
Date Updated:

Company Totals

Time Range	Reserve Category	PJMCZ	TEST_CZ	AP	AEP	DAY	DLCO	CE	ATSI	DEOK	EKPC	DOM	RTO Total
0m-30m	OPERATING Reserve	3578		27	1915	370	41	966	979	197	438	749	9260
0m-10m	PRIMARY Reserve	1296		23	434	157	40	325	322	145	37	562	3341
	SYNCHRONIZED Reserve	776		17	45	157	40	325	320	145	37	419	2281
	Non-synchronized Reserve (Quick Start)	520		6	389	0	0	0	2	0	0	143	1060
	.. NSR Hydro	223		6	389	0	0	0	0	0	0	143	761
	.. NSR Other	297		0	0	0	0	0	2	0	0	0	299
10m-30m	Secondary Reserve	2282		4	1481	213	1	641	657	52	401	187	5919
30m-180m	Beyond Secondary	1810		29	179	105	15	1695	724	181	0	510	5248

Apply Sort/Filter | Refresh | Main Menu | Help

Note: Regulation assignments should not be included in the Synchronized Reserves unless the reserve is beyond the regulation bandwidth.
**Please see the Help button for an explanation.
All numbers on this form have been rounded for display.

Unit Data

Unit Name	ACAP	Unit Type	Zone	Eco Max	Real-Time MW	Regulating	Synchronized Reserves	Quick Start NSR	Secondary	Beyond Secondary
	39	Nug		0	134	0	0	0	0	0
	892	CT		0	0	0	0	0	0	0
	885	CT		0	909	0	0	0	0	0
	800	Steam		0	0	0	0	0	0	0
	48	CT		0	220	0	0	0	53	0
	1000	Battery		0	1210	0	0	0	0	0
	1000	Battery		0	1171	0	0	0	0	0
	650	Steam		0	617	0	5	0	0	0
	650	Steam		0	633	0	0	0	0	0
	57	Nug		0	45	0	0	0	0	0
	321	Steam		0	296	0	4	0	0	0
	378	Steam		0	336	0	10	0	13	0
	735	Steam		0	660	0	0	0	0	0
	8	CT		0	0	0	0	0	0	0
	1000	Nug		0	1196	0	0	0	0	0
	1000	Nug		0	1157	0	0	0	0	0

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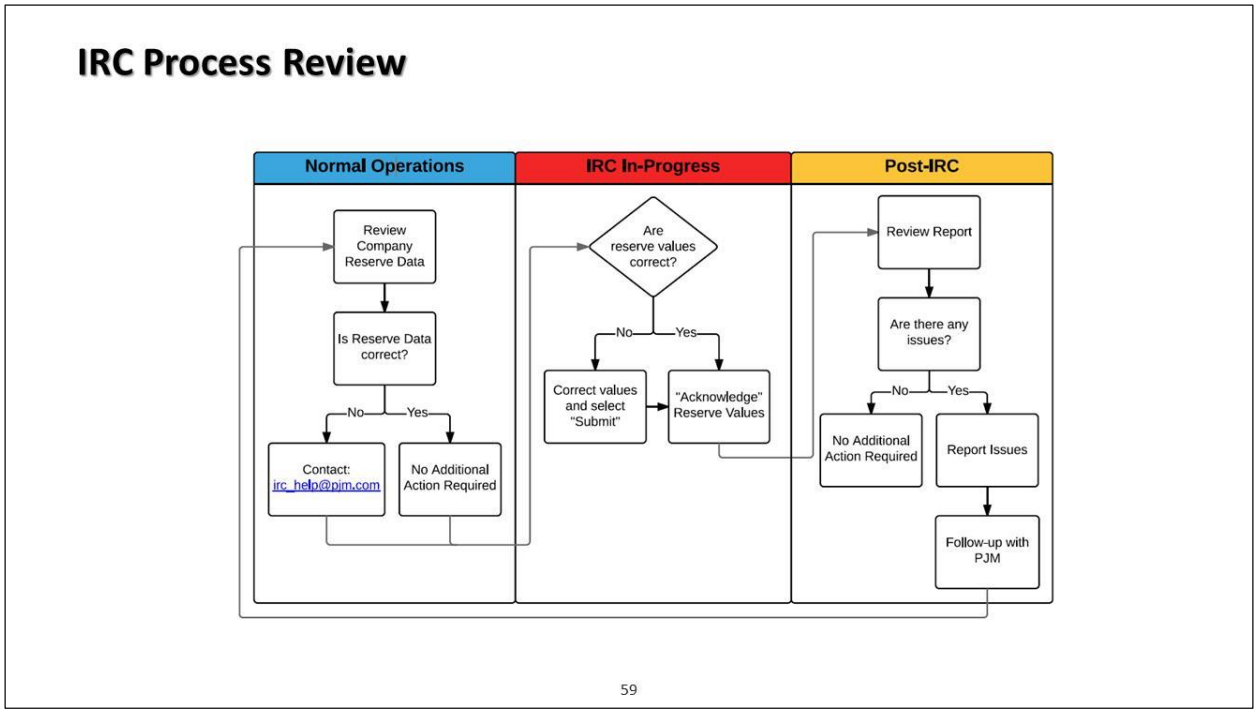
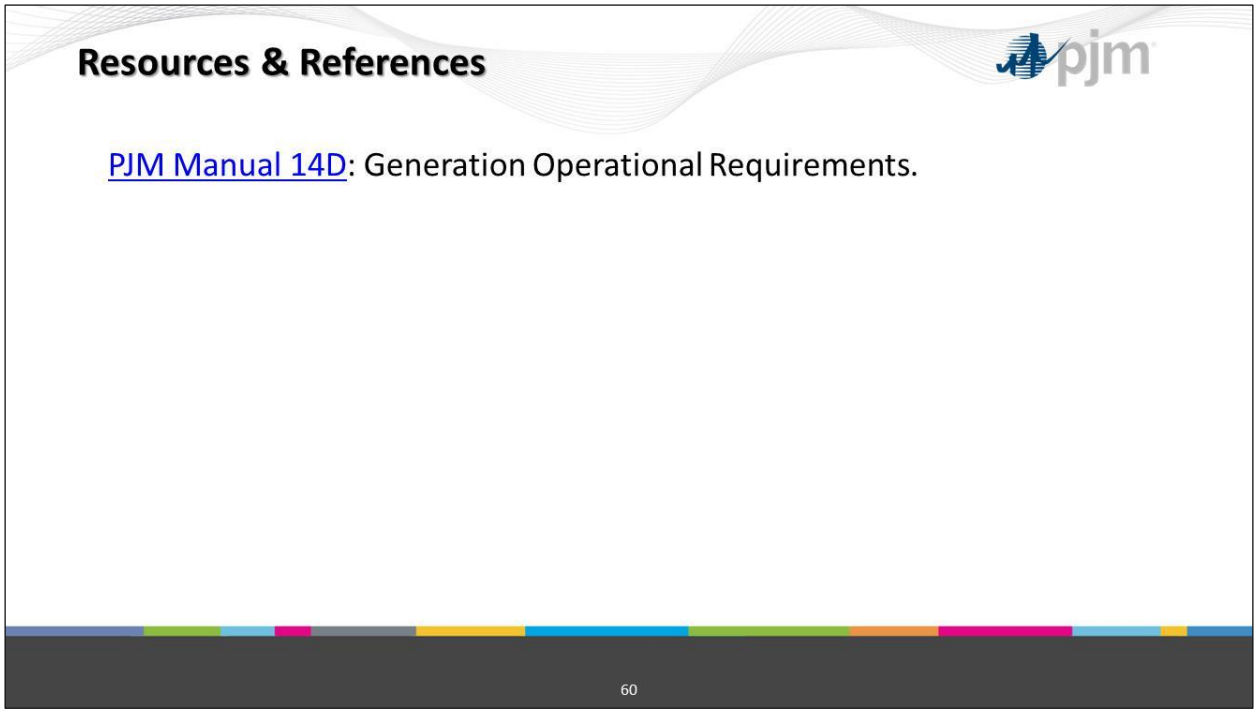
IRC Process Review



Resources & References



Summary and Questions

Summary

In this presentation, we:

- Identified the various conditions and considerations for operating during real-time
- Described the process for maintaining voltage schedules and guidelines at PJM
- Identified the reporting guidelines and process for Instantaneous Reserve Check (IRC)

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Questions

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